Develop an effective IPM Strategy to deal with pests in the Victorian Strawberry industry

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Project Number: BS08011

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the strawberry industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the Victorian Strawberry Industry Development Committee.

ISBN 0 7341 2644 1

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
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HAL

Horticulture Australia

Final Report

HAL Project BS08011 (May 2011)

Project Title: Develop an effective IPM strategy to deal with pests in the Victorian Strawberry industry.

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HAL Project- : Develop an effective IPM strategy to deal with pests in the Victorian Strawberry industry

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Purpose of the Report:

The aim of this project was to enable Victorian strawberry growers to implement an IPM strategy that will mitigate the damage caused by Western flower thrips and two-spotted mite in particular, as these pests are insecticide resistant.

Funding Sources: This project has been funded by HAL using voluntary contributions from the Australian strawberry industry (Strawberries Australia) with matched funds from the Australian Government.

Contents

Media Summary

At the commencement of this project the Victorian strawberry industry was facing a crisis in the form of insecticide resistant insects and mites. In particular, western flower thrips (WFT) and two-spotted mite (TSM) were causing significant problems as growers tried to deal with them using a pesticide-based approach. These pests were threatening the viability of individual farms and also the Victorian strawberry industry.

This project has developed an alternative method of controlling these key pests, and also all other pests, for those growers who want to use it. An Integrated Pest Management (IPM) strategy has been developed that has biological and cultural controls as the basis for managing pests, with insecticides or miticides used only as support tools (not as the primary control).

The biological control agents used in the strategy include both naturally occurring and commercially produced predatory insects and mites. The commercially produced species include the predatory mites Persimilis, Hypoaspis and Cucumeris. Naturally occurring species include predatory thrips (Haplothrips), brown lacewings, damsel bugs, hoverflies and predatory mites.

Cultural control methods may include removal of heavily infested leaf material, weed management, grass inter-rows, the use of covers or not, and plant canopy management.

Chemical control options within the strategy rely on minimal pesticide use and the use of selective or low-residual products where available. Reports from local resellers are that sales of Lannate® and dimethoate (previously the

mainstays of crop protection in the industry) are down by 80% since the commencement of this project.

Many Victorian strawberry growers are now successfully- using the IPM strategy (as outlined in Appendix 1 of this report). Adoption of this strategy has been extremely high, in terms of the percentage of strawberry production now using IPM, and rapid compared to most IPM projects (worldwide). We estimate that over 50% of Victorian production is now achieved using IPM.

Technical Summary

At the commencement of this project the Victorian strawberry industry was facing a crisis in the form of insecticide resistant insects and mites. In particular, western flower thrips (*Frankliniella occidentalis*) and two-spotted mite (*Tetranychus urticae*) were causing significant problems as growers tried to deal with them using a pesticide-based approach. These pests were threatening the viability of individual farms and also the Victorian strawberry industry, as assessed by the Victorian Strawberry Industry Development Committee (VSIDC). As a result, a *Crisis Meeting* was held at the Department of Primary Industries (DPI), Knoxfield in 2008, with entomologists from around Australia attending.

This project has developed an alternative method of controlling these key pests, and also all other pests, and is available for those growers who want to use it. An Integrated Pest Management (IPM) strategy has been developed that has biological and cultural controls as the basis for managing pests, with insecticides or miticides used only as support tools (not as the primary control).

The biological control agents used in the strategy include both naturally occurring and commercially produced predatory insects and mites. The commercially produced species include the predatory mites Persimilis (*Phytoseiulus persimilis*), Hypoaspis (*Hypoaspis miles*) -and Cucumeris (*Neoseiulus cucumeris*). Naturally occurring species include predatory thrips (*Haplothrips victoriensis*), brown lacewings (*Micromus tasmaniae*), damsel bugs (*Nabis kinbergii*), hoverflies (Syrphidae) and predatory mites (various species, including *Neoseiulus wearnii*).

Cultural control methods may include removal of heavily infested leaf material, weed management, grass inter-rows, the use of covers or not, and plant canopy management.

Chemical control options within the strategy rely on minimal pesticide use and the use of selective or low-residual products where available. Reports from local resellers are that sales of Lannate® (methomyl) and Rogor ® (dimethoate) (previously the mainstays of crop protection in the industry) are down by 80% since the commencement of this project. Integrating the use of pesticides with the biological control agents (both naturally occurring and commercially produced) is an extremely important component of the IPM strategy. Minimising all pesticide applications is the aim, but when necessary the most selective insecticides need to be selected.

Many Victorian strawberry growers are now successfully - using the IPM strategy (as is outlined in Appendix 1 of this report). Adoption of this strategy has been extremely high, in terms of the percentage of strawberry production now using IPM, and rapid compared to most IPM projects (worldwide). We estimate that over 50% of Victorian production is now achieved using IPM.

Introduction

This project was commenced because of concerns by the Victorian Strawberry Industry Development Committee (VSIDC) about the viability of the Victorian Strawberry industry because of problems with insecticide resistance in two major pests: western flower thrips (*Frankliniella occidentalis*) and twospotted mite (*Tetranychus urticae*). In August 2008 the industry held a crisis meeting at the offices of Department of Primary Industries (DPI), Knoxfield, where it was stated that some growers have faced large losses despite frequent application of insecticides, and insecticide residues in fruit was of concern. The VSIDC felt that "the industry may be decimated within 2-3 years" if these pests were not dealt with in an improved way.

Documents circulated by the Industry Development Officer (IDO) to people attending the meeting included three examples of growers approach to dealing with the pest. The use of Lannate® (methomyl) was a major part of their approach, and in the non-harvesting season, Regent® (fipronil) was also used. Also of concern to the industry were detections of fipronil residues in Victorian strawberries in 2007-08 (ref: http://new.dpi.vic.gov.au/agriculture/about-agriculture/publications-resources/produce-monitoring-report). The industry was keen to develop a method of controlling these key, insecticide resistant pests that would allow growers to deal with these pests without pesticide residues and other related concerns.

This project was undertaken with the aim of enabling Victorian strawberry growers to implement an Integrated Pest Management (IPM) strategy that would mitigate the damage caused by western flower thrips (WFT) and two-spotted mite (TSM) in particular, as these pests are insecticide resistant. The main output would be a written strategy to deal with insect pests in strawberries that growers could use as an alternative to the current pesticide-based approach. This would mean that they would not be totally dependent on pesticides being available as the only means of controlling pests, especially insecticide resistant pests.

Materials and Methods

Initial Awareness training

A series of 4 workshops explaining what was involved in an IPM approach was the initial activity carried out with Victorian strawberry growers. These were conducted by Paul Horne and Jessica Page at 3 locations in the Yarra Valley and approximately 65 growers attended. This was a significant proportion of the Victorian industry (approximately 110 farms). The workshops resulted in a number of growers wanting to try an IPM approach on their farms.

Developing an IPM Strategy

The first activity for field monitoring of WFT was to develop a sampling method that could be used to compare sites and follow trends in WFT populations at individual sites. The method needed to be simple and quick so that several sites on one or more farms could be checked regularly. A standard method that we developed was to take 10 newly opened flowers at random from any block that needed monitoring. The assumption was that this sample would be representative of the block. The purpose of the sampling was to provide some estimate of whether the WFT population within the block being sampled was trending up or down. It was not intended as an absolute measure of population size, but as a means of following population trends in a block over time, and to have some idea of the relative pest pressure on different farms.

As well as monitoring for WFT, the project needed to identify the full range of pests and all key beneficial species. Similarly, suitable cultural control options (eg. leaf-removal, crop hygiene) that could impact on pests or beneficials needed to be identified and trialled. To achieve this, we carried out regular monitoring at several sites as originally proposed. However, we also carried out less frequent monitoring but made observations and gave IPM advice at a much larger number of sites than initially planned.

The key sites for data collection on WFT population trends were as follows:

Year 1
Mick and Nancy Pignataro; Wombat Berries; Oz Fresh, Rewards

Year 2
Mick and Nancy Pignataro; Sweet Berries; OzFresh, Rewards

Year 3
Wombat Berries; Field Connection (OzFresh); ASD (2 sites)

Many other farms were assisted with trialling an IPM approach, but the main data collection points were from the above farms

Laboratory testing of potential key native predators

A laboratory colony of western flower thrips was established and maintained by IPM Technologies P/L. This allowed testing of potential predators and in particular, *Haplothrips victoriensis*, to see if they accepted western flower thrips as food.

Adoption of IPM

There are two separate measures of adoption of IPM as a result of this project. One is from a survey of growers conducted by the IDO (Jason Hingston) in early 2011 and the other is an additional count of growers that we have dealt with in person and believe are using IPM (most of whom are listed in the Acknowledgements section of this report). The survey of growers asked for their location, size (ha), number of plants, current control methods (eg, IPM, Pesticides, IPM + pesticides, Organic), whether or not mites were released to control two-spotted mite or western flower thrips, whether or not certain insecticides were used more than twice (Lannate®, HyMal®, Success®, Acramite®, Vertimec® and Ambush®), and then asked to rate success out of 5 (1 = None, 5 = Total success) for each of several pests including twospotted mite and western flower thrips (the key targets of this project).

Pest and Beneficial Poster

It was initially proposed that a web-site for strawberry growers would be developed as part of this project, with the aim of providing photos of key species. However, the industry and IPM Technologies felt that a poster would be more practical for most in the industry at this stage. Therefore we spent a larger amount of time to find and photograph a much larger number of insects than originally intended, and spent a much greater amount of time providing on-farm advice to those growers wanting to change to an IPM approach.

Results

Control Strategies

A successful strategy to deal with western flower thrips in Victorian strawberry crops has been developed in this project (Appendix 1). This has been based on biological and cultural methods, with support as required by minimal use of insecticides and miticides. The results are shown by the graphs of pest numbers at a range of sites, based on monitoring over several years, as shown in the next section of the report.

Monitoring of WFT Populations

Figure 1: Counts of Plague thrips and Western flower thrips (female, male and juveniles) at site 1.

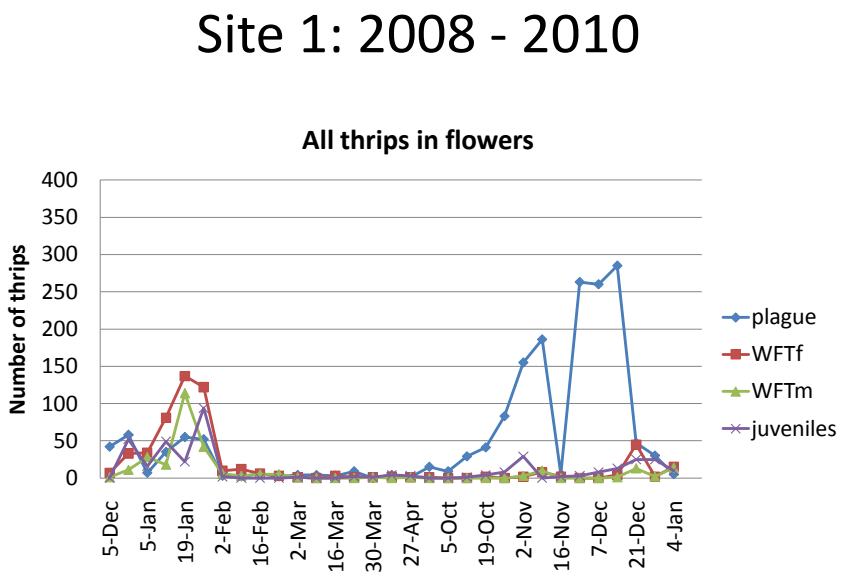
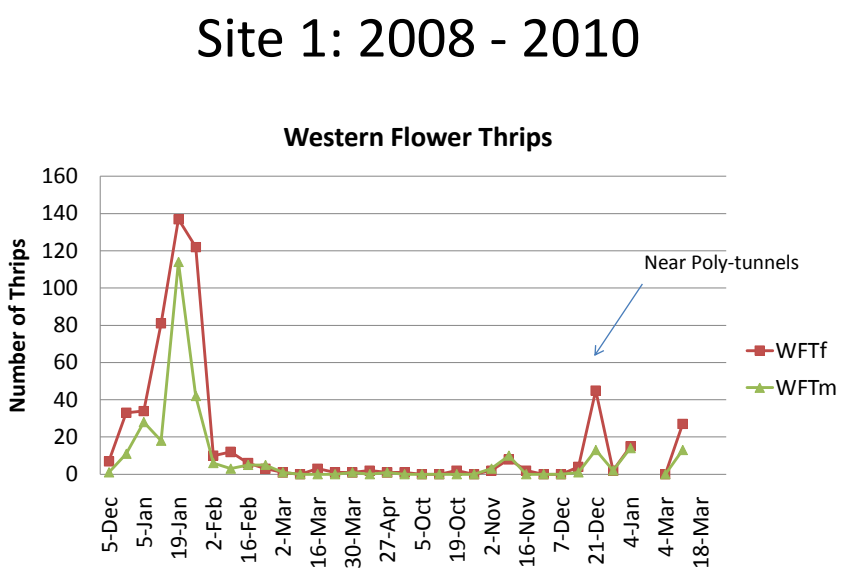


Figure 2: Counts of Western flower thrips at site 1



The two graphs above illustrate successful control of western flower thrips using IPM. Numbers of WFT were initially extremely high, but once insecticide applications ceased in January 2009, then control was achieved. (The insecticides prior to that time were targeting thrips). It is important to note that no insecticides for western flower thrips after the first week of January 2009.

Figure 3: Counts of Western flower thrips at site 2.

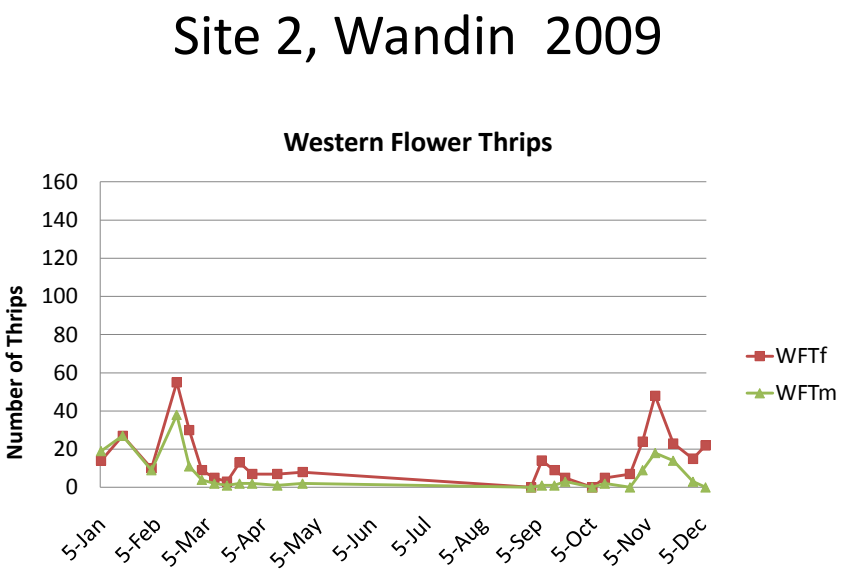
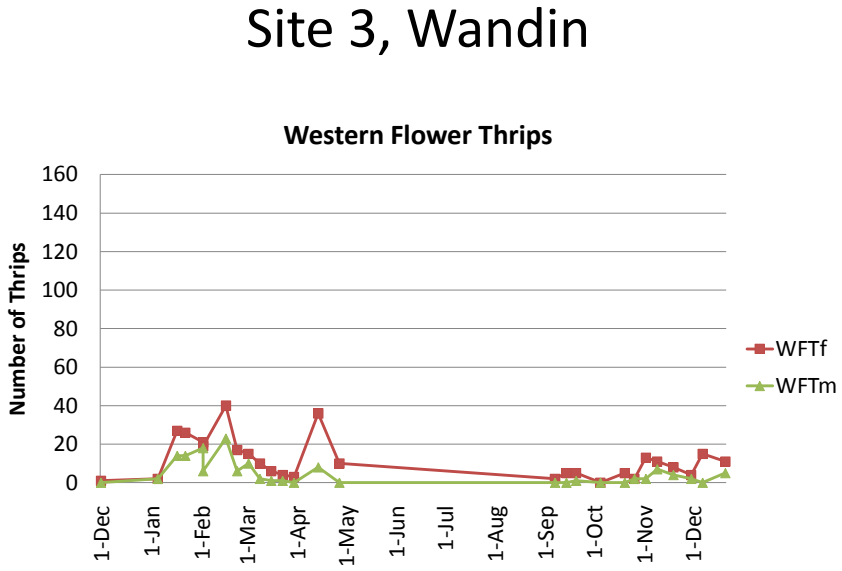


Figure 4: Counts of Western flower thrips at site 3.



At sites 2 and 3 the counts of WFT were not as high as at site 1, but an IPM approach was shown to control the pest. Monitoring ceased in late December when the grower decided to revert to using regular insecticides for the remainder of the season.

At site 4 the graphs below illustrate the difference between a regular spray programme and an IPM approach being implemented.

Figure 5: Counts of Western flower thrips where conventional spraying was applied

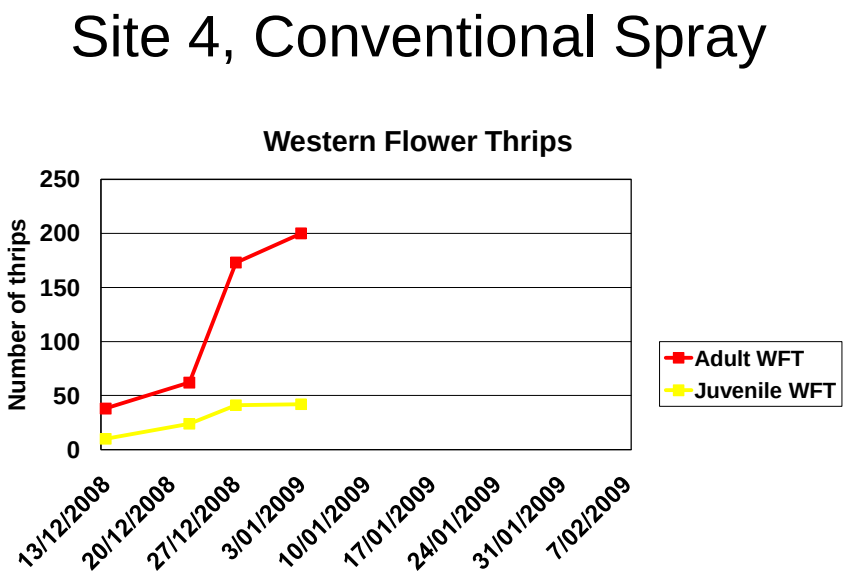


Figure 6: Counts of Western flower thrips where IPM used

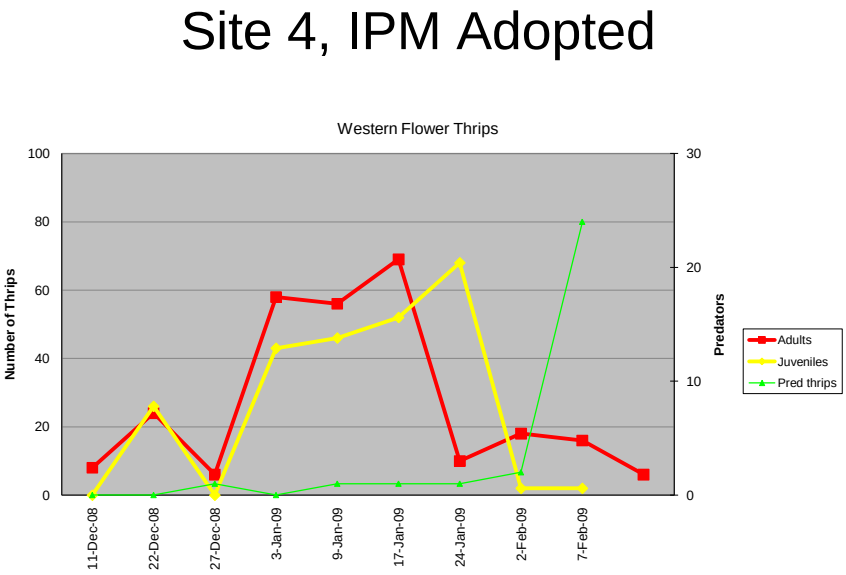


Figure 7: Counts of Western flower thrips where IPM implemented on new plants at site 5.

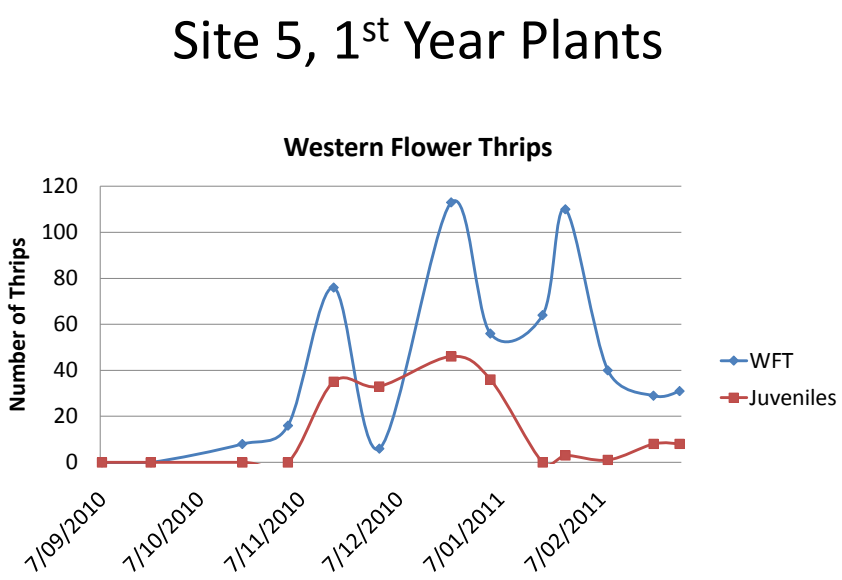


Figure 8: Counts of Western flower thrips where IPM implemented on 2nd Year plants

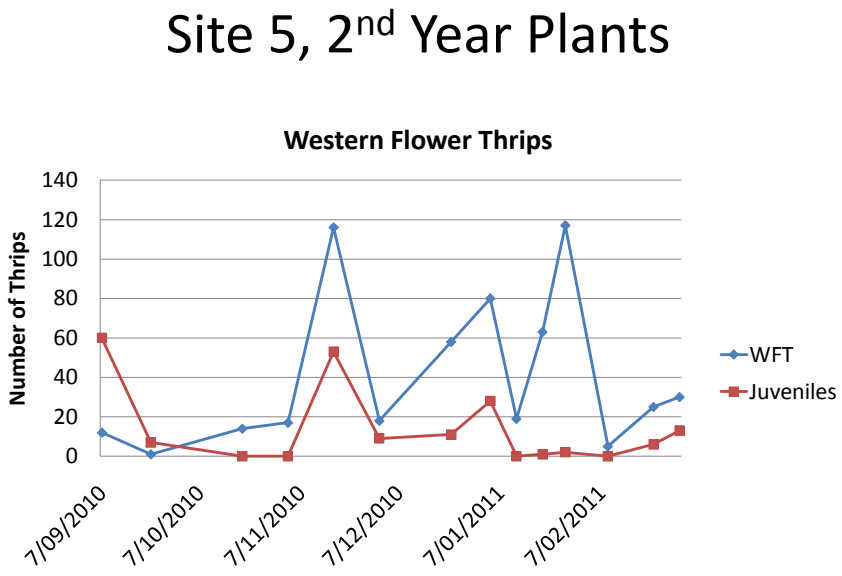
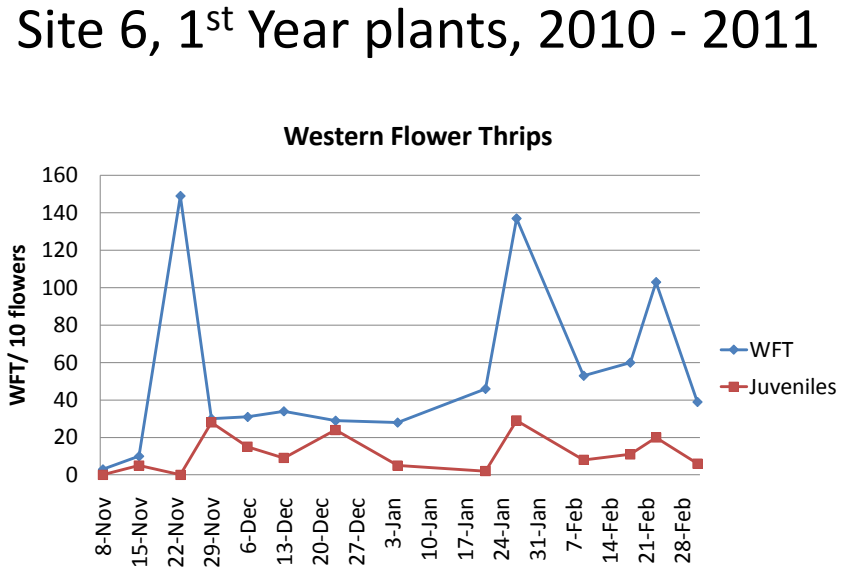


Figure 9: Counts of Western flower thrips at site 6



At all but one site (site 7) where we were involved via this project, proper adoption of the IPM strategy as described in Appendix 1 achieved good results in control of western flower thrips. At site 7, although numbers of western flower thrips were initially low in new plants, they rose steadily throughout the growing season (Figure 10). This was not due to any application of insecticides that were incompatible with IPM, and this was confirmed by the fact that control of two-spotted mite by Persimilis remained good throughout the season. Another factor local to this site was likely to be involved.

The level of Plague Thrips (*Thrips imaginis*) was much lower in the 2010 – 2011 season than the previous year (Figure 11). As a result, insecticides targeting plague thrips were also generally less in the latest season. The results are from sticky traps placed in Wandin crops.

Figure 10: Counts of Western flower thrips in 1st year plants where IPM was used

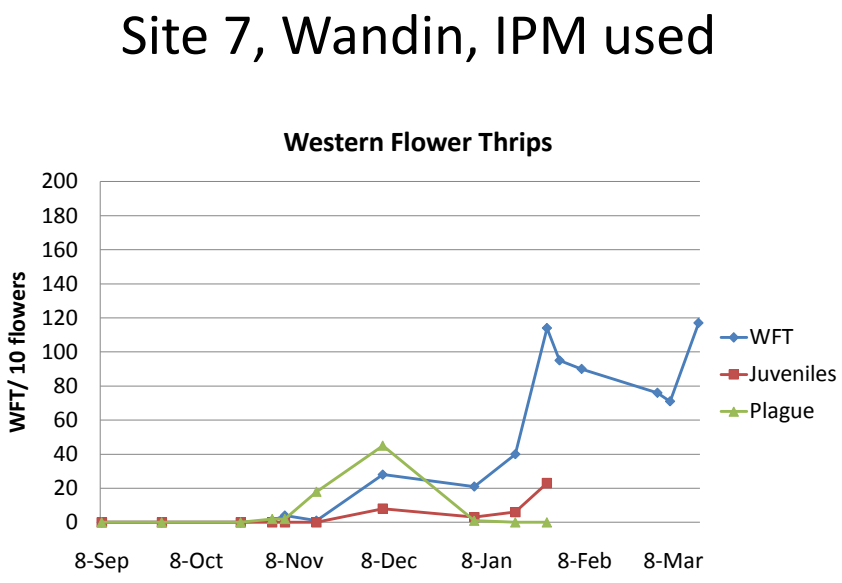
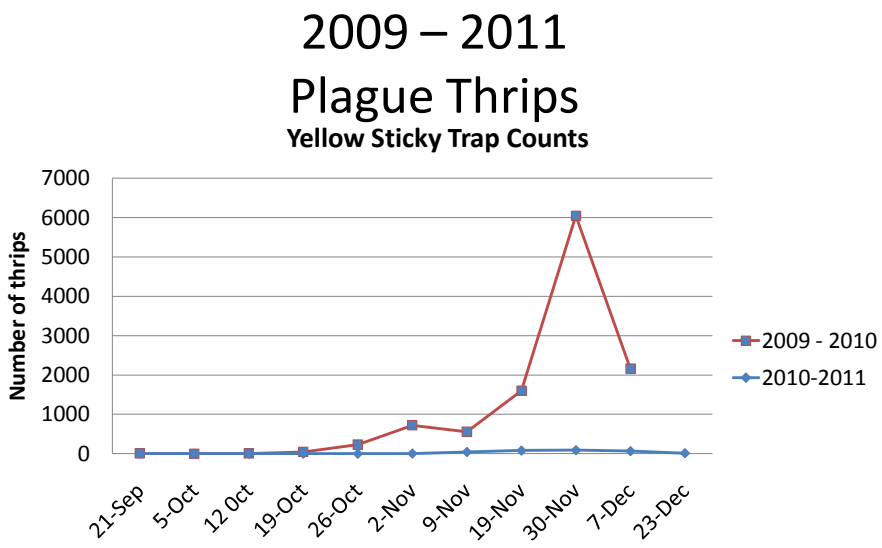


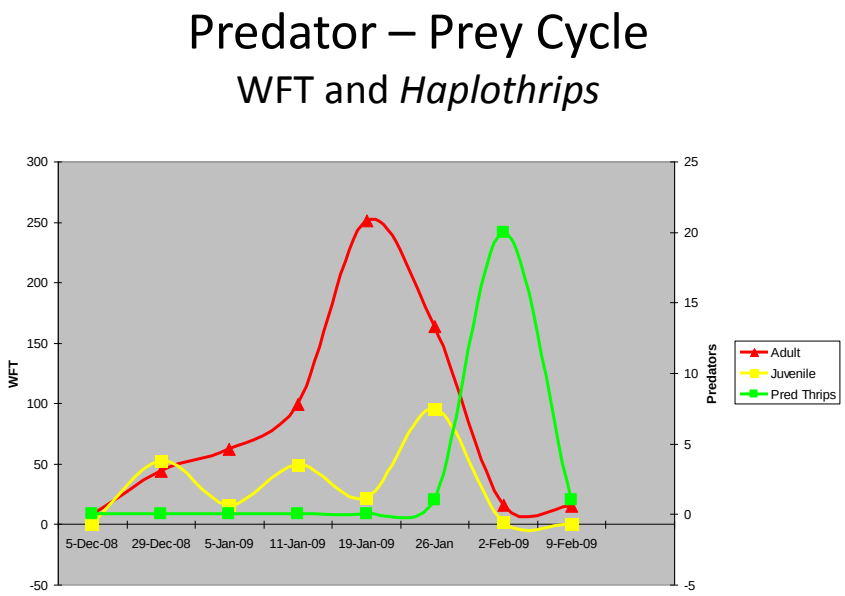
Figure 11: Counts of Plague thrips in Wandin, 2009 - 2011



Haplothrips impact on WFT

We were able to keep a population of *Haplothrips victoriensis* in the laboratory for over 12 months on a diet of only western flower thrips. They can feed on other insects and mites, but when present they can certainly have a massive impact on western flower thrips in the field. Figure 12 shows the predator-prey cycle involving western flower thrips and *Haplothrips victoriensis.* Sprays of insecticides such as Success® (spinosad) will kill plague thrips but will also kill *Haplothrips*.

Figure 12: Counts of *Haplothrips* (predator) and Western flower thrips (prey) at Site 1 in Wandin.



Adoption of IPM

IDO Survey

The survey of IPM adoption and measure of success has been provided to HAL as a separate Excel file. The results are summarized here.

Twenty farms responded, 19 gave their location, and all gave the number of plants that they grew (total 7,558,000 plants) representing about 30% of the Victorian industry. The majority (16/19) were from the Yarra Valley.

Responses to the question regarding type of control measures currently used are summarised in Table 1 below.

Table 1: Control measures used by strawberry growers

Type of Control Used	Number	%
IPM	9	45
IPM + Pesticides	6	30
Pesticides only	1	5
Organic	3	15
No answer	1	5
Total:	20	100

The total number saying that they used IPM, whether alone or adding that they used pesticides is 75% of respondents. The number saying they used only pesticides is much lower at 5%.

The answers to whether or not commercially reared mites were released to control two-spotted mite or western flower thrips totalled as follows: 17/20 (85%) said that they released Persimilis for control of twospotted mite, while 13/20 (65%) said they used predators for western flower thrips. The main reason for the difference is that the three Organic farms (15% of respondents) did not release predators for western flower thrips.

Only two of those responding to the survey said that they had used Lannate more than twice in the season, which is a large change since the crisis meeting held at Knoxfield in 2008. 13/20 (65%) said they did not use Lannate® more than twice and 4 gave no answer. However, of those 4, 3 were organic and one was IPM only, and so it could be assumed that in fact 18/20 (90%) no longer used Lannate®.

The final questions in the survey were regarding the degree of success that IPM had achieved in controlling key pests, and this included twospotted mite and western flower thrips. Those rating a 4 or 5 (ie. highly or totally successful) were as follows:
Mites: 17/20 (85%)
WFT: 10/20 (50%)
Of these, those who rated the IPM approach as 5 (Total Success) for each of these pests were:
Mites: 10/20 (50%)
WFT: 3/20 (15%)
Those who rated the IPM success as poor (rating 1 or 2) for each pest was as follows:
Mites: 1/20 (5%)
WFT: 4/20 (20%)
The one respondent who rated it as poor for mite control was one of the two growers still using Lannate® more than twice per season, and three of the four rating it poor for WFT still used pesticides (one being the same farmer using Lannate®). The remaining grower of the four did not give a category for the type of control used.

The survey responses for the IDO totalled 7,558,000 plants, which he estimates is close to 1/3 of the Victorian industry. However, we concluded from the location of the farms and their size that it does not include at least some of the growers, including at least one major producer, that we know have successfully implemented IPM.

Identification Guide

A poster has been produced for the strawberry industry which illustrates the key species (pests, beneficials and others) that are commonly seen in Victorian strawberry crops. The species illustrated are the most important insects and mites in these crops.

Discussion and Conclusions

A strategy has been developed and implemented successfully by several strawberry growers on their farms in Victoria (estimated at around 50% of the industry, and possibly much more (75%) in terms of number of plants) during the course of this project. It has also resulted in significant changes to the strawberry industry in South Australia, where 6 out of 8 major commercial producers have changed to using the same IPM strategy (source: James Altmann, Biological Services, Loxton).

The project commenced with an awareness raising exercise about what was involved with IPM, by running a series of workshops on IPM for interested growers. This certainly helped to get interest in IPM but by no means were all growers convinced or interested. During this project we worked solely with growers who were interested in receiving our advice on IPM. We accept and encourage the view that IPM is available for everyone but not everyone wants it. This project has provided an alternative approach to dealing with the key pests in strawberries for those growers who are interested in using it.

Controlling two-spotted mite with persimilis is the first essential step in the strategy, in order to eliminate miticide applications. This is necessary as the key commercially produced predators of western flower thrips are mites. A key part of the IPM strategy is to eliminate broad-spectrum insecticides, as these will impact on key predators of both two-spotted mites and western flower thrips.

A very real measure of the success of this project is the reduction in the use of Lannate® (methomyl), Rogor® (dimethoate) and Regent® (fipronil). John Frisina (Branch Manager of the Wandin Landmark store) reports that (total) sales of Lannate® and Dimethoate are down by around 80% since the commencement of this project, and sales of Regent® have practically ceased. (Note that sales are for all potential uses in a range of crops, not just strawberries, but we believe there is a direct correlation).

The control of western flower thrips was the main focus of this project and the growers who used the strategy described here effectively controlled this pest. Western flower thrips is an

extremely serious pest, worldwide, in a range of crops and attempts to control it often fail. Estimates of losses in the Netherlands in 1998 for glasshouse crops alone due solely to western flower thrips were $49 million (Kirk 2002). An estimate of its pest status is reflected in the number of scientific studies on this species alone. Although there are over 5,000 species of thrips, one-third of all publications on thrips in the last 30 years are devoted to western flower thrips (Reitz 2009).

Even in this project, although a strategy has been developed it still has to incorporate site-specific issues and these are not always easy to identify, let alone solve. For example at Site 7 in this study, western flower thrips numbers increased gradually throughout the growing season despite following the same procedure as at other sites where control was much better. Discussions with the farmer involved have identified two possible causes and further changes will be implemented next season. However, the main result of this project has been the rapid change in adoption of IPM as the basis for controlling western flower thrips in strawberry crops in Victoria and south Australia.

Control of two-spotted mite on farms using IPM was in many cases much better than on farms using a conventional pesticide-based strategy, particularly at the end of the season (data provided by Craig Purdham, EE Muirs & Sons, Silvan). This is also shown in the survey conducted by IDO (Jason Hingston) where 85% of those responding regarded control of mites using IPM as extremely good. This has implications for long-term control of both of these pest species as high levels of pests at the end of one season means a carry-over of pests for the start of the next season. Growers not carrying high levels of mites or thrips into the next season will have far fewer problems and costs associated with these pests in the following season.

This project has identified the native thrips species *Haplothrips victoriensis* as a key predator of western flower thrips. It had previously been recorded in the scientific literature only as a predator of mites in lucerne (Bailey and Caon 1986). Sprays of Success® (spinosad) targeting other pests including plague thrips will kill the predatory thrips. Therefore an assessment needs to be made as to the value of such sprays when firstly, plague thrips may cause less damage than previously thought on the varieties of strawberries that are currently grown, and secondly, the sprays cause the loss of a key predator of a major pest (WFT).

The survey conducted by the IDO and our estimate both put adoption rates at a high level (between 50 and 75% of the industry) within the three years of this project, which is an extremely high level and rate of adoption compared to world experience (Bajwa and Kogan 2003, Herbert 1995). We attribute this entirely to our approach of working directly with interested farmers on their farms, so that they are participating in the research and are directly involved in trials (Horne, Page and Nicholson 2008). The importance of this aspect of the project cannot be over-estimated. The availability of IPM experts to assist growers one-on one on their own farms as a part of this project was a key aspect of the success in terms of adoption of IPM and control of western flower thrips. Tools such as the identification poster are useful in support of IPM but are not sufficient to implement changed practice.

It is also interesting that 30% of those responding to the survey said they used IPM plus pesticides, indicating a possible mis-interpretation of IPM as meaning only using biological control. IPM can and does involve the use of pesticides, but the type and frequency are the key issues. This is an aspect that could be addressed further in any future work. Also of note is that the three organic farms involved in the survey did not release predators for western flower thrips, which is strong support for the contention that western flower thrips is usually a pest induced by broad-spectrum insecticides.

Many different factors can influence pollination of strawberries and thus influence the formation of the berry. Anything that disrupts pollination, even partially, can cause mis-shapen fruit. These factors include mildew, temperature, weather conditions and some insects. However, it is quite possible that the role of some insects has been over-estimated in the past, or with other varieties. While there is no doubt that some insect species are clearly responsible for particular types of damage, there needs to be more clarification about the role of species such as plague thrips and lygaeid bugs in particular, and what if any thresholds could be established for the varieties that are now grown. We suggest that this could be the subject of research in the future.

We are aware of researchers in New Zealand that have developed and made commercially available an attractant for western flower thrips, for use in glasshouse and polyhouse environments. The current formulation is not suited to hot and dry conditions or high pest populations, but appears to be of use with milder conditions and low pest numbers. Work on

better formulations of this product to allow extended use periods could be extremely valuable, as would trials on the effectiveness of mass-trapping in cooler months. The product is not an insecticide and is not going to affect populations of beneficial species and so if efficacy could be improved then it would be a useful addition to the existing IPM strategy.

Communications/ Extension

Results of this project have been communicated to the strawberry industry throughout the course of the project by way of articles in the industry newsletter, field days and talks. However, a large effort has been made to visit growers individually when they requested it, to help them make the change to using IPM. This has been by far the most successful means of assisting IPM adoption, and is illustrated by the high level of adoption in terms of the proportion of the industry using IPM. The other communication methods raise awareness but are not as effective in implementing change.

The written strategy and a companion poster illustrating relevant pest and beneficial species will be available to Victorian strawberry growers at the conclusion of this project.

Recommendations:

This report and the strategy that has been developed can now form the basis of control of western flower thrips in Victorian strawberry crops. We recommend that the strawberry industry promote the use of this strategy amongst its members.

We also recommend that the strategy would be improved if some further research was able to refine aspects of the strategy that could lead to better pest control and reduced insecticide use. In particular to:

1. Investigate the threshold level of plague thrips before insecticide applications are warranted in the varieties now grown in Victoria
2. Look at the impact of removing leaf material on the effectiveness of Cucumeris
3. Evaluate the impact of different species of true bugs (especially lygaeid bugs) in distorting berries

4. Assess the potential of chemical lures for monitoring and mass-trapping western flower thrips.

Acknowledgements

We would like to thank the following groups and individuals and especially Sam Violi and John Hasan, as well as the whole VSIDC for their strong support for the initial project proposal and throughout the course of the project. We would like to acknowledge the collaboration provided by two agronomists - John Frisina (Landmark, Wandin) and Craig Purdham (EE Muir & Sons, Silvan) who assisted us throughout the course of the project. Most importantly we thank the following farmers who allowed us to work with them on this project: John and Annette Hasan, Wombat Berries (Eddie, Bobby and Clarissa), Mick and Nancy Pignataro, Maria and Santo Faella, Tom and David Palmucci, ASD (Ripepi family), Steve Riccardi, Tony and Francis Caltieri,, Mauro Di'Ulio, Serge and Adrian Di'Ulio, Mark and Joe Di'Ulio, Dominic and Tony Di'Ulio, Dominic and Adrian Celante, Ben DiFilipas, Field Connection (OzFresh), Mick Molluso and especially Jim Corrone. We also thank the producers of beneficial insects and mites, who responded by increasing production to meet the demands suddenly made by the Victorian strawberry industry as a result of this project. In particular, James Altmann (Biological Services) responded with a markedly increased production of Cucumeris, and also on many occasions the supply (at no charge) of additional product where it was requested by us for this project. We thank the current IDO, Jason Hingston, for his assistance with many activities during the course of this project, and also the previous IDO, Elizabeth Wharton, for the initial contact with us.

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Appendix 1: AN IPM STRATEGY FOR THE CONTROL OF PESTS IN VICTORIAN STRAWBERRY CROPS

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May 2011

What is IPM?

Integrated Pest Management or IPM is a strategy for controlling pests in any crop using a combination of biological, cultural and chemical controls. The key to any successful IPM strategy is looking at the system as a whole and not treating each problem in isolation. In other words making sure the control of one pest is not creating problems with another pest. Some insects and mites that have short life cycles develop resistance to chemicals very quickly, particularly mites, thrips, aphids and whitefly. Growers often turn to IPM when this happens. A good IPM strategy is able to deal with insecticide resistant pests by simply allowing beneficial insects and mites to do most of the work. Regardless of how many insecticides a pest is resistant to they can never become resistant to predators.

Initially IPM seems more complex than a pesticide based approach. To make a decision when relying only on pesticides the grower needs to know what the target pest is and choose a product that kills it. To make a decision when using IPM the grower needs to know what the pest is and what eats it, what are other likely pests and what eats them and what impact each pesticide has not only on the target pest but also on all the beneficial species in the crop. The aim of this guide is to provide Victorian strawberry growers wanting to use IPM with the information they need to make the right decisions. As growers become more familiar with using IPM it will seem far less complex than trying to kill pests with pesticides that don't work.

Pesticides

All pesticides will kill or disrupt something, after all that is what they are designed to do. Some are, of course, more disruptive than others but even the pesticides that are considered "soft" or safe can have a negative impact on some species. The difficulty is in knowing or finding out what that impact will be. Testing a product to see if it safe to beneficials is a lot more complex than testing a product to see if it kills a pest.

Often the impact on beneficial species is more subtle than just simply killing them. Some chemicals can reduce the amount of eggs they lay or kill only one life stage or maybe only kill some of the population. These results initially may not be as bad as killing 100% out-right but can still have a very significant impact particularly when relying on these species for control. When using biological control agents it is important, especially for Western flower thrips and two-spotted mite control, that all the predators are in peak condition and there needs to be as many as possible. If the predators are not laying as many eggs as they used to or if a few are being killed each week it is enough for the pests to get away.

The pesticides listed in this strategy have been chosen because they are the most compatible products available at this stage, but this does not mean they are totally safe. Of the products listed some have been tested on some of the key beneficials. The information in this strategy is based on one application at the label rate.

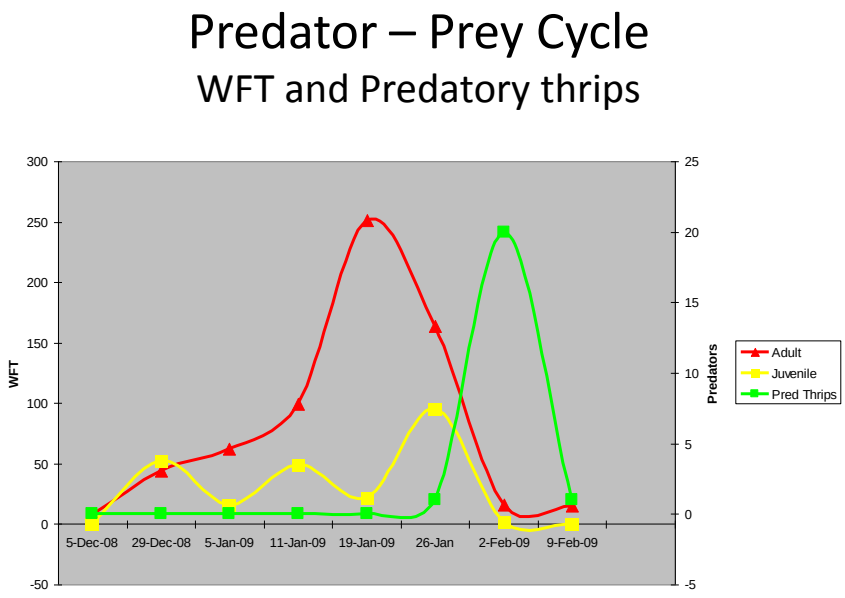
Predators and Prey

The interaction between pests and beneficials is called a predator prey cycle. It is the same interaction that happens between foxes and rabbits, two-spotted mite and persimilis and western flower thrips and cucumeris. The number of pests increases when conditions favour them, such as good weather and unlimited food, the predators then respond because they now have unlimited food. So for a short time there are lots of pests and lots of predators. Eventually the predators no longer have enough food to support their population because they have eaten most of it i.e. the pests are gone. So the predator population goes back down again.

This is what happens repeatedly in a strawberry crop and is important to understand because it is when this cycle is disrupted that the pest population can flare. For example spraying for mirids before the persimilis have controlled the two-spotted mite could cause the mite population to explode but waiting for another two weeks until the persimilis have eaten most of the mites and the problem can be avoided.

This cycle also shows that it is not necessary to always have high populations of beneficial species, that actually the aim is to have both pest and beneficial at level that is difficult to find. The data used to make the graph below is from strawberry crops in Wandin.

Predator – Prey Cycle



A Proposed IPM Strategy for Victorian Strawberries

Pest	Beneficial	Cultural	Chemical
Two-spotted mite	Persimilis, Stethorus, Mite B	Healthy plants, overhead irrigation to keep plants clean and increase humidity when it is hot and dry.	Acramite Milbenknock Omite
Western Flower thrips	Cucumeris , Haplothrips, Hypoaspis, predatory bugs	Canopy management to protect beneficials.	None *Lures?
Crop Mirid	Damsel Bugs	Control Cape weed, wire weed and prevent weed from going to seed.	Hy-Mal
Aphids	Ladybirds, Brown lacewings, Hoverflies and Aphidius		Pirimor
Rutherglen Bugs	Damsel bugs	Control Cape weed, wire weed and prevent weed from going to seed.	
Plague thrips	-	-	Success
Whitefly	Encarsia, Eretmoceras		Confidor (not as a spray)
Lygaeid bugs	Damsel bugs	Control Cape weed, wire-weed and prevent weed from going to seed.	Hy-Mal
Caterpillars	Damsel bugs, parasites, predatory bugs		Dipel, Success
Carpophilus beetle		Remove rotting fruit	*Trap
Vinegar fly	Wasp parasites	Remove rotting fruit	

PESTS

Two-spotted mite- *Tetranychus urticae*

Biology

Development from egg to adult ranges from 7 days to several weeks depending on temperature. Two-spotted mite lives on a range of plant species and the females can survive over winter which means they can carry over easily from one season to the next. They are very small - about 0.5mm and the juvenile stage looks similar to the adult. The eggs are round, shiny and pale yellow, and it is best to use a hand lens to find them.

Mites prefer new growth and the underside of leaves. They damage the plant cells causing the leaves to have a silvery mottled appearance. If the population is high then plant vigour can be affected; if it is extremely high then the plant may be killed. A low to medium level (meaning they can be found after a short search) is usually fine as long as there are predators breeding in the crop.

Control Options

Two-spotted mite problems are often associated with the frequent use of pesticides which kill the mites natural enemies. Control of two-spotted mite without the regular use of miticides is essential for an IPM strategy to be successfully implemented. The most common predatory mite is persimilis (*Phytoseiulus persimilis*) which is commercially available. There are also naturally occurring predatory mite species as well as a mite eating ladybird called Stethorus that help to control two-spotted mite.

Miticides such as Acramite, Omite and Milbeknock can be used if necessary but should only be used to support the predatory species. The primary control must be biological if an IPM strategy is being used.

Western Flower Thrips – *Frankliniella occidentalis*


Biology

Adult Western flower thrips develop from egg to adult in about 2-3 weeks in summer but take longer over winter. The adults lay their eggs in plant tissue (often in the flower buds); the juveniles then emerge and feed by rasping the plant cells causing scarring or bronzing to the growing fruit. They do not cause distortion to the berries.

Adult western flower thrips can fly but do not disperse in large flights like plague thrips. Populations carry over on farms or move in from edges.

Western flower thrips problems are associated with the frequent use of pesticides that kill their natural enemies. They are rarely a problem in systems that do not use regular applications of pesticides. *Once the population is very high it can be **extremely** difficult to control. All pesticide applications should be considered with this in mind.

Control options

Because Western flower thrips develops resistance so quickly relying on insecticides for control is not sustainable. There are however many beneficial insects and mites that give very good, sustainable control if not disrupted. Some are commercially available such as Cucumeris and Hypoaspis and others turn up naturally (such as predatory thrips called Haplothrips) and other predatory mites and predatory bugs. Control with pesticides is not considered an option within an IPM strategy.

Crop Mirid – *Sidnea kinbergi*

Biology

Crop mirids are true bugs and belong to the insect family Miridae which are common pests in other crops such as cotton and lucerne. Mirids feed by piercing the plant tissue and injecting a chemical which kills the surrounding cells causing distortion to the developing fruit or pod. In strawberries the distortion gives the fruit a distinctive turban like appearance which is caused by the nymphs feeding in the flowers.

Crop mirids have a preference for feeding in new flowers and so can cause significantly more distortion than other similar species which prefer feeding on seeds. Unlike Rutherglen bug, crop mirids do not fly in large numbers which means adults may not be noticed until they begin breeding within the crop and the fruit is damaged. The bright green juvenile stage is often easier to see than the brown adults. The juveniles look similar to aphids but they have longer antennae which are striped and they move quickly when disturbed. Like similar bug species they lay their eggs within the plant tissue and there are several generations a year.

Control Options

Damsel bugs prey on a range of insects including juvenile crop mirids and can be found in very high numbers in strawberry crops so are important biological control agents.

A key factor in controlling bugs is weed control. Crop mirids particularly like flowering brassicas and sow thistle so controlling these weeds before they flower will help considerably. If spraying for weeds along an edge check for bugs and if present consider also using a broad-spectrum insecticide. Otherwise just killing the weeds will force them into the crop.

Mirids are most likely to be problem in 2nd year plants as they can carry over from the previous season, possibly from a flight in late Autumn. Look for turban shaped fruit early in the season and for juveniles in the flowers.
At this stage the only product registered is Hy-Mal, and this can be sprayed at a low rate targeting the flowers (lightly over the top). Hy-Mal is a broad-spectrum insecticide so frequent use will be highly disruptive. If Western flower thrips and Two-spotted mites are not under control then the damage caused by mirids should be considered in relation to the damage caused by the two main pests and the decision to spray should be made accordingly.

*Be careful not to confuse mirids with other less damaging bugs such as lygaeids.

Aphids (different species)

Biology

Aphids are most common in early spring and autumn. Winged adults fly into the crop and begin to reproduce. Pest aphids are almost all female and give birth to live young so a population can build very quickly. Aphids breed in the crown of strawberry plants and on the underside of leaves. They are sucking insects and produce sticky honeydew that can cause sooty mould.

Control Options

There are many beneficial insects that can give good control of aphids these include ladybirds, brown lacewings, hoverflies and parasitic wasps. These predators and parasites are very abundant in spring and autumn because they are responding to the abundance of aphids which they feed on. In most situations they will clean up the aphids and there is no need to use an insecticide. If beneficial insects are not enough on their own then Pirimor can be used. Pirimor will kill Cucumeris, hoverflies and adult wasps but is the least disruptive chemical option available at this stage.

Often the decision to spray for aphids is made just as the beneficial insects are about to get on top of them. It is a good idea to have a good look for all life stages of the key beneficials before making the decision to spray.

Rutherglen bug- *Nysius vinitor*

Biology

Rutherglen bugs live on a range of weed and native plant species. When their host plants dry out in early summer large populations of Rutherglen bugs disperse on warm northerly winds.

In late Spring and Summer development from egg to adult takes about 4 weeks. Females can lay up to 400 eggs and there are several generations a year.

Rutherglen bugs are seed feeders and so are more attracted to the fruit than the flowers. They can be a problem as a contaminant and can also taint the fruit with their smell. They are often more visible or active on warm overcast days.

Control Options

In some years populations of Rutherglen bugs can reach enormous numbers, overwhelming any possible biological control agent. There are no selective insecticides available and so control relies on the use of a registered broad-spectrum insecticide targeting the adults. In most years this is not necessary and the population can be maintained by good weed control. Weeds such as Cape weed and wire weed are excellent hosts for Rutherglen bug as well as sow thistle and any weed that has gone to seed. Spraying a broad-spectrum insecticide in the inter-rows and the base of the plastic instead of over the whole crop is also an option but be very careful of drift. Also including an insecticide

when spraying for weeds along an edge can help lower the population (Sprayseed on its own is not enough).

If they are breeding in the crop then there are beneficial insects that can help to control the population. Damsel bugs feed on the juvenile stages and are very abundant in strawberry crops.
Hy-Mal is the only chemical option at this stage so the decision to spray for Rutherglen bugs should take into consideration the impact that Hy-Mal will have on the control of Two-spotted mite and Western flower thrips.

Plague thrips- *Thrips imaginis*

Biology

Plague thrips are dispersed by warm northerly winds in late December when the bush and grass dries out. They can reach very high numbers at this time but the peak of the flight is usually over in a couple of weeks. The damage caused by plague thrips is not well proven and it is likely that current strawberry varieties can tolerate a much higher level than previously believed. They are unlikely to cause distortion to the fruit in the varieties currently available and they may even help with pollination. Plague thrips generally do not breed in strawberry crops but feed and then move on. Because they do not breed within the crop they do not develop resistance to insecticides as quickly as Western flower thrips.

Control Options

When they arrive in huge numbers Plague thrips overwhelm any potential biological control. If control is considered necessary then the least disruptive insecticide available at this stage for use against plague thrips is Success. Success will kill predatory thrips that feed on Western flower thrips, adult wasps that help control aphids and whitefly, Orius that also helps to control Western Flower thrips and also Stethorus that feeds on Two-spotted mite.

Regular sprays of Success will interfere with the control of Western flower thrips and whitefly.

Greenhouse whitefly - *Trialeurodes vaporiorum*

Biology

Whiteflies are sap sucking insects that secrete sticky honeydew. If the population of whitefly is very high then the amount of honeydew and sooty mould which grows on the honeydew can affect the vigour of the plant. The adults lay eggs on the new leaves and can be difficult to see. The nymphs look like flat, oval-shaped scales stuck to the underside of the leaf. They are cream coloured and are often mistaken for eggs. The nymphs pupate after a few weeks and the adult whiteflies emerge. Egg to adult takes about 4 weeks in warm weather.

Control Options

Whitefly can reach high numbers at the end of the season but usually at this stage damage, if any, is minimal. If there is a local source of whitefly then they can reach damaging levels earlier and become a problem. Whitefly, like two-spotted mite and Western flower thrips, is resistant to many insecticides so the chemical control options are limited. There are beneficial insects that can provide very good control of whitefly. The most important are two very small parasitic wasps called Encarsia and Eretmoceras. Encarsia are commercially available and Eretmoceras are naturally occurring. The wasps are not very efficient over winter but work very well in late spring and summer. The adult wasps are easily killed by Pirimor and Success.

Lygaeid bugs – several species

Biology

There are many species of bugs that can be found in Strawberry crops most of which cause very little (if any) damage. Lygaeids are mostly seed feeding bugs so do not cause the same distortion to the fruit as mirids. They can be a problem at times as a contaminant in the punnets. They tend to be more active on warm, still, overcast days.

Control Options

With all bugs weed control is very important. Avoid providing them with a good habitat to breed in. Cape weed, wire-weed and any weed that has gone to seed will favour bugs. When spraying for weeds it's a good idea to check if they are harbouring bugs, and if they are then include a broad-spectrum insecticide. Once they are in the crop they are very difficult to contact with an insecticide because they live very low in the plant so are protected. The best time to spray for them is after the plants have been cleaned or trimmed. Then an insecticide aimed at the inter-row will help.

*Remember that they are a minor pest and that Damsel bugs eat them.

Caterpillars

Biology

Caterpillars can be a problem in strawberries by feeding in the flowers and small fruit. The main species are Light Brown Apple Moth, Loopers and Heliothis. The adult moths fly into the crop and lay their eggs and move on. Egg to adult takes about 4 weeks for most species.

Control Options

There are a range of insects that parasitise these species as well as predatory bugs such as damsel bugs and shield bugs that eat them. Bt sprays such as Dipel are the safest spray to use for caterpillars. Bt stands for Bacillus thuringiensis which is a bacteria that only kills caterpillars and so is safe to all beneficials. Bt sprays are UV sensitive and so need to be sprayed late in the day after the peak UV time has passed. Vivus or Gemstar are also very safe to all beneficials. These are similar to Bt but contain a virus that will only kill Heliothis caterpillars so it is important to know which species is the target. Success is also a caterpillar spray but does kill some beneficial species such as wasps, predatory thrips and Orius.

Carpophilus beetle and Vinegar Fly

Biology

Adult beetles and flies are good flyers and are attracted to rotting fruit. The adults lay their eggs on ripe or rotting fruit. The larvae feed inside the fruit and then pupate in the ground. Over summer, egg to adult takes about 4 weeks. Carpophilus beetle and Vinegar fly are favoured by wet summers and lots of rotting fruit which often go together.

Control Options

The key to control is farm hygiene. Remove all rotting fruit throughout summer and destroy it. These pests are good flyers so can easily fly back into the crop so it is important to make sure that the pile of removed fruit does become a source of the pests. Pheromone traps are also a very good way to control Carpophilus beetle however they have recently been taken off the market. Hopefully they will become available again in the future

Beneficial Species

Persimilis-*Phytoseiulus persimilis*

Development from egg to adult is similar to that of two-spotted mite, ranging from 10 days to several weeks depending on temperature. Persimilis only eats two-spotted mite so their life cycles are linked (see graph). Persimilis prefer slightly humid conditions and so perform better when protected by foliage. As well as providing them with a good habitat the foliage provides some protection from pesticide sprays including fungicides. For this reason establishment in 1st year plants can be slow if the plants are not touching. Monitor for persimilis by looking for eggs and adults near two-spotted mite. Persimilis eggs are oval shaped and pale orange and slightly larger than two-spotted mite eggs. Eggs are an indicator that they are happy and breeding.

Persimilis are tolerant to Milbenknock, Acramite and Omite but it is still best to avoid using repeated applications of these chemicals. It is important that persimilis is allowed to be the primary control agent of two-spotted mite and chemicals are only used to support them when necessary. Vertimec, HyMal, and Paramite will have a negative impact on Persimilis populations.

Stethorus – *Stethorus* sp.

Stethorus is a small species of ladybird about 3mm across. They feed on pest mites such as two-spotted mite and are very good at controlling large populations. The juvenile stage look like small grey grubs, and they grow to about 4mm in length before pupating and turning into adult beetles. Egg to adult takes about 3 to 4 weeks. Stethorus are killed by Success, Hy-Mal and Vertimec

Neoseiulus – *Neoseiulus wearneii*

Neoseiulus are naturally occurring predatory mites that feed on Two-spotted mite. They are more tolerant to some conditions and chemicals than Persimilis however when conditions are right Persimilis will out compete them. An abundance of these mites can be an indicator that there is something disrupting

the system. They can be found near populations of two-spotted mite, they are pear shaped and are pale yellow. They are now commercially available. Killed by Vertimec, Hy-Mal, Paramite.

Cucumeris – *Neoseiulus cucumeris*

Cucumeris are commercially available predatory mites that feed on eggs and juvenile Western flower thrips. Cucumeris are tiny mites and that can be very difficult to find. The easiest place to see them is under the calyx of green fruit. Cucumeris should be released at the first sign of Western flower thrips or when new plants have flowers, the pollen provides them with an alternative food source. It is important to remember when using Cucumeris that the initial release is an inoculation only and it is the subsequent generations that will give control. In other words they cannot simply be replaced after being killed by an insecticide. The true benefits of using biological control come from allowing beneficial insects and mites to thrive in your crop. Killed by Vertimec, Hy-Mal, Paramite and Pirimor.

Hypoaspis – *Hypoaspis miles*

Hypoaspis are soil dwelling mites that feed on thrips pupae and fly larvae in the soil so help with control of Western flower thrips. Because they live in the soil they are protected from most foliar applications of pesticides.

Haplothrips – *Haplothrips victoriensis*


Haplothrips are naturally occurring predatory thrips that feed on other thrips. They can be found in flowers where they feed and lay their eggs. The juvenile stage is bright red and looks like a very small chilli! They are an important biological control agent for Western flower thrips. Their life cycle takes about 4 to 6 weeks. They are killed by Success and Hy-Mal

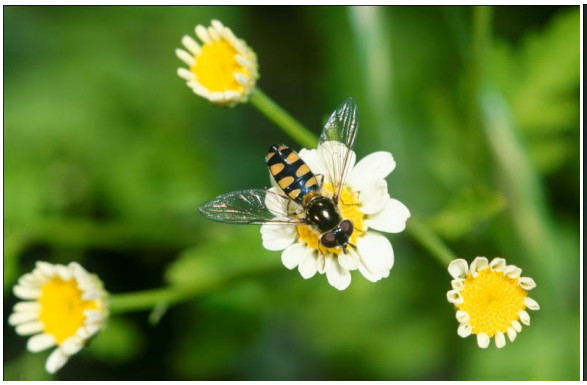
Ladybirds – Various species

Adult ladybirds fly into strawberry crops in spring in search of aphids. If there are many aphids they will lay eggs. Juvenile ladybirds do not look like a beetle but more like a black grub. They are voracious eaters and will consume many aphids before they pupate and turn into an adult. Egg to adult takes about 4 weeks in warm weather.

Brown Lacewings – *Micromus tasmaniae*


Brown lacewings are very important in controlling aphids. There is often a big flight of brown lacewings in spring but they can also be found throughout winter in 2nd year plants. The juveniles do most of the feeding and can be found low in the plant searching for food. Their eggs can be found on the underside of leaves near colonies of aphids, they are oval, and are a pearly pink colour, and laid flat on the leaf. Killed by Hy-Mal and Vertimec.

Hoverflies - *Syrphidae*




Hoverflies look like little bees and can often be seen hovering around flowers. The adults only feed on pollen but the maggot is an excellent aphid predator. Killed by Success and HyMal.

Aphidius wasps – *Aphidius* species

Aphidius is a parasitic wasp that lives inside an aphid. The adult wasp stings and lays an egg inside an aphid, the aphid stays alive while the wasp maggot lives inside its body. After about 10 days when the maggot is big or when the maggot is big enough the aphid dies and is turned into a bronze coloured ball, this is the wasps cocoon called a mummy. The wasp then emerges and parasitizes more aphids. Aphidius wasps only sting aphids. They are killed by Pirimor and Success

Damsel bugs – *Nabis kinbergii*

Damsel bugs are true bugs so are in the same group (Order) of insects as mirids however they are predatory and do not feed on plants. They have a long straw like mouth that they use to stab and suck out the insides of their prey. They feed on small caterpillars, aphids and the juvenile stages of pest bugs such as mirids and Rutherglen bugs. The juvenile stage looks similar to the adult but does not have wings. They can be very abundant in strawberry crops and are probably undervalued as biological control agents. They can be found throughout winter so have the potential to carry over into the next season and are favoured by lots of foliage. Be careful not to confuse them pest species. Killed by Proclaim, HyMal

Springtails - *Collembola*

Springtails or Collembola are detritus feeders and live in moist leaf litter, at times they can also be found in strawberry flowers. They are not a pest but are an important part of the food chain. They are included here because they can be very abundant at times and it is important that they are not confused with being a pest.

Encarsia- *Encarsia formosa & Eretmoceras (Eretmoceras* sp)

Encarsia is a tiny wasp that is a parasite of whitefly. The female wasp lays her eggs in whitefly larvae (which are commonly called scale). The wasp maggot then develops inside the scale until it is ready to pupate. If the whitefly has been parasitized the scale will turn black and an Encarsia wasp will emerge. If it has not been parasitized it will stay white and a whitefly will emerge. Encarsia are commercially available and can be released from late spring and throughout summer. Eretmoceras are very similar to Encarsia except that they turn the scale dark yellow instead of black and they are naturally occurring. Both species are killed by sprays of Success.

This IPM strategy was developed to deal with the most important mite and insect pests found in Victorian strawberry crops during the life of this project. This strategy will no doubt change or be revised in the future as new products come on the market and old ones are removed or as new pests arrive and old pests are no longer important. Regardless of the changes the underlying principle remains the same, there are three control options biological, cultural and chemical that must be integrated so that control of one pest does not interfere with the control of another pest. In other words - all available tools to control pests have to work together in a compatible way.

Acknowledgements:

We would like to thank the VSIDC and all of the strawberry growers who have been involved with this project over the last 3 years. Photographs of insects and mites used in this strategy and for the companion poster were taken by Denis Crawford, Graphic Science except where stated on the poster.